Deep Space Network Capabilities and Costs

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Service Providers

- NASA’s Procedures and Guidelines (NPG) 7120.5D require all programs/projects to develop requirements for space operations services provided by NASA facilities during mission formulation. Such services include communications, tracking, mission operations, navigation, and data processing. NPG 7120.5D requires projects to use NASA services unless a more cost-effective life cycle can be found and demonstrated in the proposal.

- Programs/projects are free to propose procurement of services from sources other than NASA. Projects should conduct trade studies comparing the use of NASA-provided services with any proposed alternatives.

- If you do choose to use non-NASA assets for part of your mission, you are strongly encouraged to enlist the DSN as a facilitator to ensure compatibility and speedy transfer of responsibility and data turnover

- NASA’s Science Mission Directorate ha a policy that no mission may require a downlink capacity greater than a single 34m antenna

- All requirements for ground systems coverage are negotiated thru the Space Communications and Navigation Division at NASA HQ

Costing Policy

- As a matter of policy, NASA includes estimated costs for mission operations and communications services, as well as an assessment of key parameters for mission operations, in the evaluation and selection processes of all Earth-orbiting and deep space missions. NASA is implementing this policy to:
  - implement formal NASA-wide full-cost accounting,
  - better manage NASA's heavily subscribed communications resources,
  - promote tradeoffs between on-board processing and storage vs. communications requirements, and
  - encourage hardware and operations system designs minimizing life cycle costs while accomplishing the highest-priority science objectives.

DSN Services

Service Category	Brief Description of Service's Content
Command	RF modulation, transmission, and delivery of telecommands to spacecraft.
Telemetry	Telemetry data capture and additional value-added data routing and processing.
Mission Data Management	Data buffering, staging, short and long term storage.
Tracking and Navigation	Radio metric data capture, LEOP trajectory, ephemerides, and modeling.
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Flight Engineering	Telecommunications link performance, analysis, and prediction and time correlation.
Beacon Tone	Monitors subcarrier frequencies transmitted by S/C indicating S/C's health.
Ground Communications	Data, voice, and video communications network services.
Radio Science	S/C Doppler, range, and open-loop receiver measurements at 2, 8, and 32 GHz.
Radio Astronomy / VLBI	Similar to Radio Science but measures natural phenomena. Wide & narrowband VLBI.
Radar Science	Transmits RF carrier toward user defined target; captures reflected signal.

Contacting the DSN

The primary DSMS point of contact for this AO is the Commitments Office Manager

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Space Link Extension

Project Operation Control Centers (POCCs) using DSN and SN services should use a standard *Space Link Extension* (SLE) *Services Interface* for transferring data to and from DSN sites.

This interface is designed to provide international control center–network interoperability and reduce mission risk by facilitating the rapid substitution of a different earth station, not necessarily only NASA's, in the event of a failure.

The SLE Services interface requires POCCs to directly access DSN stations for the following services: Command Link Transmission Unit (CLTU), Return All Frames (RAF), Return Channel Frames (RCF), and CCSDS File Delivery Protocol (CFDP).

Six international space agencies, including: ASI, CNES, DLR, ESA, JAXA, and NASA, have agreed to implement the SLE Services Interface to achieve full international interoperability. Interface architecture conforms to standards adopted by the CCSDS.

Frequencies

- **X-Band and Ka-Band Communications**

- Deep space (r ≥ 2 x 10 6 km) missions operating in a *Space Research* should be designed to communicate in either the 7/32 GHz or, as a fall back, 7/8 GHz bands.
- Ever increasing congestion and the addition of allocations for incompatible services have restricted future; ex- operations in the 2 GHz deep space band.
- Accordingly, the Science Mission Directorate is recommending that use of the 2 GHz deep space band be limited to radio science and in-situ communications.
- Deep space missions [> 2M km] having high data rates should operate in Ka-Band (31.8 - 32.3 GHz space-to-earth) or, if using the 8400-8450 MHz band, they should comply with SFCG Recommendations regarding bandwidth-efficient modulation.
- Near Earth missions [≤ 2M km] should use the 26-27.5 GHz spectrum band. FY11.

In July 2008, NASA's Strategic Management Council agreed that missions launching in 2016 and beyond will operate at Ka band.

CCSDS File Delivery Protocol

- To improve station utilization efficiency as well as reduce mission risk and costs, all DSN users should employ the CCSDS File Delivery Protocol (CFDP), to transfer data to and from a spacecraft.
- CFDP operates over a CCSDS conventional packet telecommand, packet telemetry, or an Advanced Orbiting System (AOS) Path service link.
- CFDP enables the automatic transfer of a complete set of specified files and associated information from one storage location to another replacing an expensive labor-intensive manual method.
- It can transfer a file from a source point to a destination site using an Automatic Repeat Queuing (ARQ) protocol.
- In an *acknowledged mode*, the receiver notifies the transmitter of any undelivered file segments or ancillary data so that the missing elements can be retransmitted guaranteeing delivery.

Multiple Spacecraft Per Antenna

- Where a multiplicity of spacecraft lie within the beamwidth of a single DSN antenna, it may be possible to capture data from two or more spacecraft simultaneously using the Multiple Spacecraft Per Aperture (MSPA) system.
- MSPA decreases DSN loading and will save the project’s money

Delta Differenced One-Way Range

- Delta Differenced One-Way Range (DDOR) can be used in conjunction with Ranging and Doppler data to:
- 1) Increase spacecraft targeting accuracy (when used with range and Doppler data).
- 2) Improve mission reliability (when used with range and Doppler data).
- 3) Reduce tracking time (if pass duration is driven by tracking data capture).

DDOR observations are deemed critical to mission success for trajectory correction maneuvers, entry descent and landing, etc, and, therefore, are the only allowable exceptions to the single 34m antenna requirement.

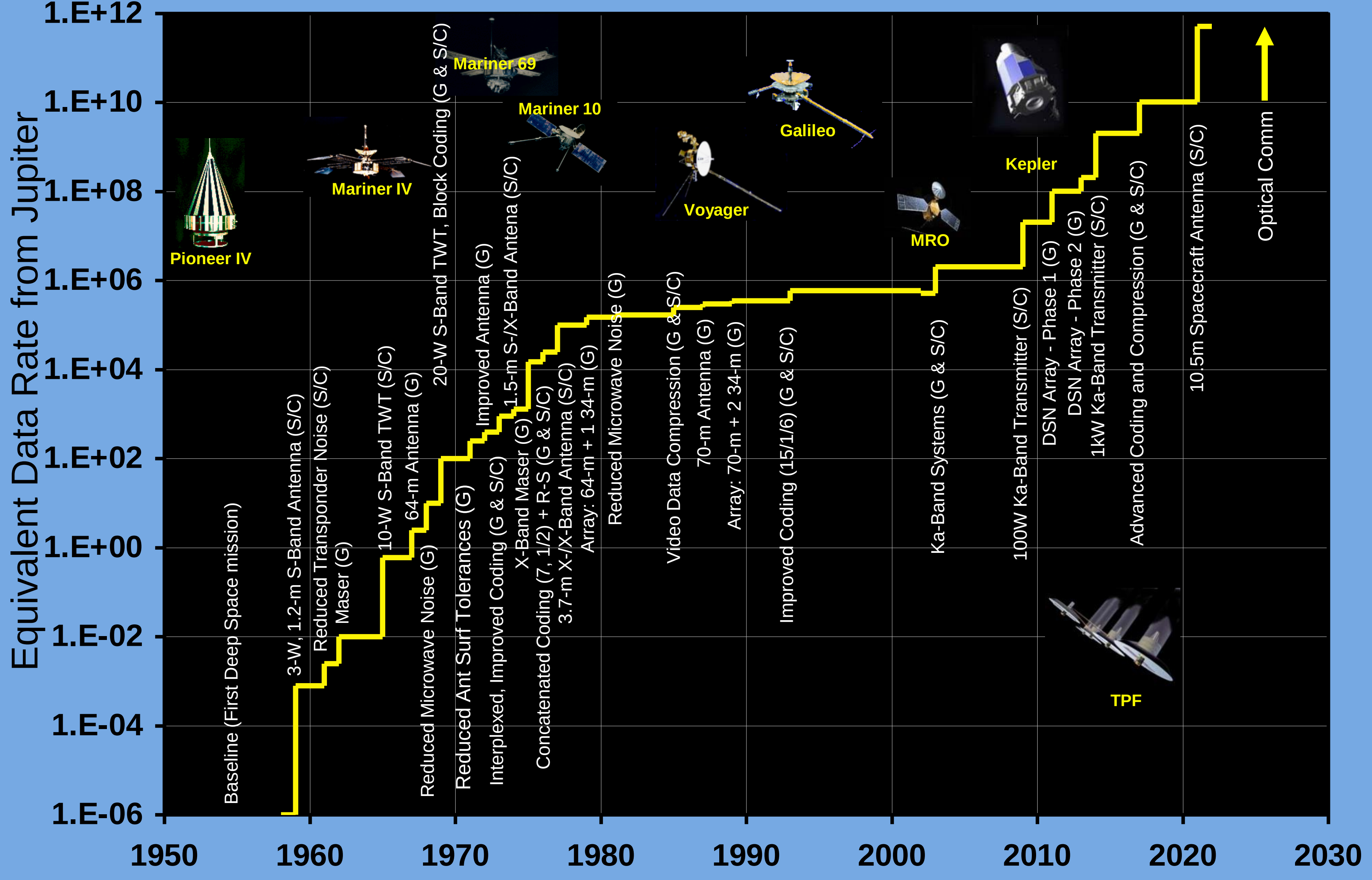
New Space Communications Capabilities Available for NASA's Discovery and New Frontier Programs

- NASA's Deep Space Network is developing technologies needed for realizing the future evolutionary systems in the NASA Strategic Plan.
- That plan is guided by four basic principles;
  - reliably achieving negotiated mission goals,
  - increasing the science data return of future missions 50X by 2015,
  - providing standard and cost effective mission interfaces, and
  - growing an evolving infrastructural architecture for seamless communications and navigation across the solar system.

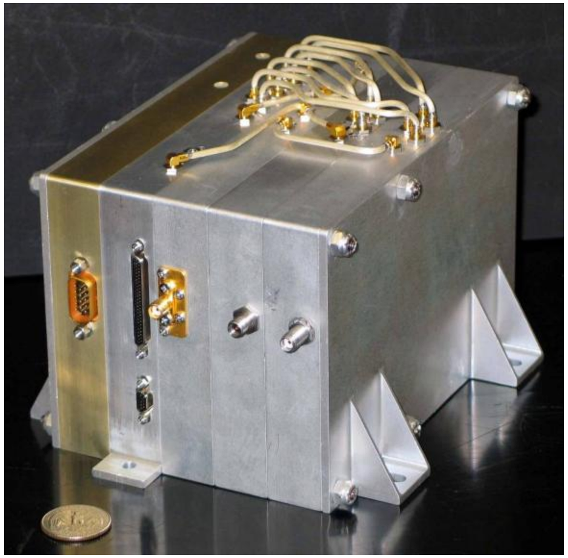
Back of the Envelope Calculation

Mission	Data Rate [Mbps]	Frequency	Ground Antenna Equivalent Aperture [m]	s/c TX Power [W]	s/c Antenna Diameter [m]
MRO –today	6	Ka	34	35	3
MRO- what might have been. I.	24	Ka	70	35	3
MRO- what might have been. II.	30	Ka	34	180	3
Next Gen Mars Mission	80	Ka	34	180	5

DSN: Looking Forward



S/Ka-Band Coherent Transceiver System



Highlights:

- Small size (16 cm x 11 cm x 11 cm)
- Low mass (2.1 kg)
- Low power (5 W receive, 11 W full duplex)
- S and Ka-Band exciters (2.2 and 26 GHz)
  - Simultaneous operation
- S-Band receiver (2.1 GHz)
- Up to 1.3 Mbps forward link data rate
- Up to 25 Mbps return link data rate

Flight Readiness Status:

- S/Ka-Band prototype qualified to TRL-6
- S-Band only flight unit plan for RBSP

Prior Generation Heritage:

- TIMED, S-Band
- CONTOUR, X-Band
- New Horizons, X-Band

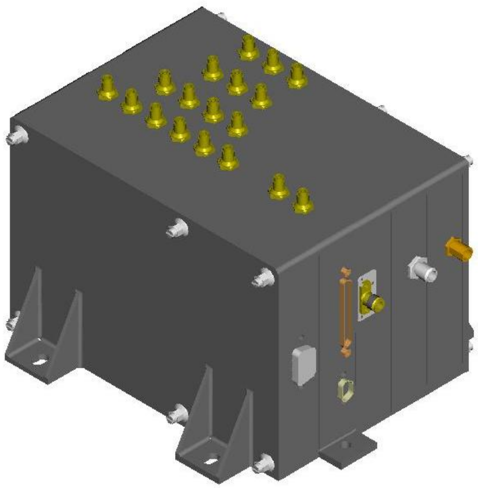
Unique Features:

- Low power and mass/ TDRS compatible (single access)
- High bit rate forward link
- Software defined radio with reprogrammability (i.e., flexible turn-around ratio, RF frequency, modulation formats, data rates, encoding, loop bandwidth)
- Internal ovenized oscillator

Targeted Users:

- TDRSS users, lunar missions, libration orbiters, MEO missions, and competed mission sets where low mass and power are desired.

X/Ka-Band Deep Space Coherent Transceiver



Highlights:

- Small size (16 cm x 11 cm x 11 cm)
- Low mass (2.2 kg)
- Low power (6 W receive, 13 W full duplex)
- X and Ka-Band exciters (8.4 and 32 GHz)
  - Simultaneous operation
- X-Band receiver (7.2 GHz)
- Up to 100 Mbps downlink data rate
- Up to 1.3 Mbps uplink data rate

Flight Readiness Status:

- X/Ka-Band prototype under development
- Plan to demonstrate TRL-6 by May 2010

Prior Generation Heritage:

- TIMED, S-Band
- CONTOUR, X-Band
- New Horizons, X-Band

Unique Features:

- Low power and mass/ DSN compatible
- High bit rate uplink
- Software defined radio with reprogrammability (i.e., flexible turn-around ratio, RF frequency, modulation formats, data rates, encoding, loop bandwidth)
- Internal ovenized oscillator

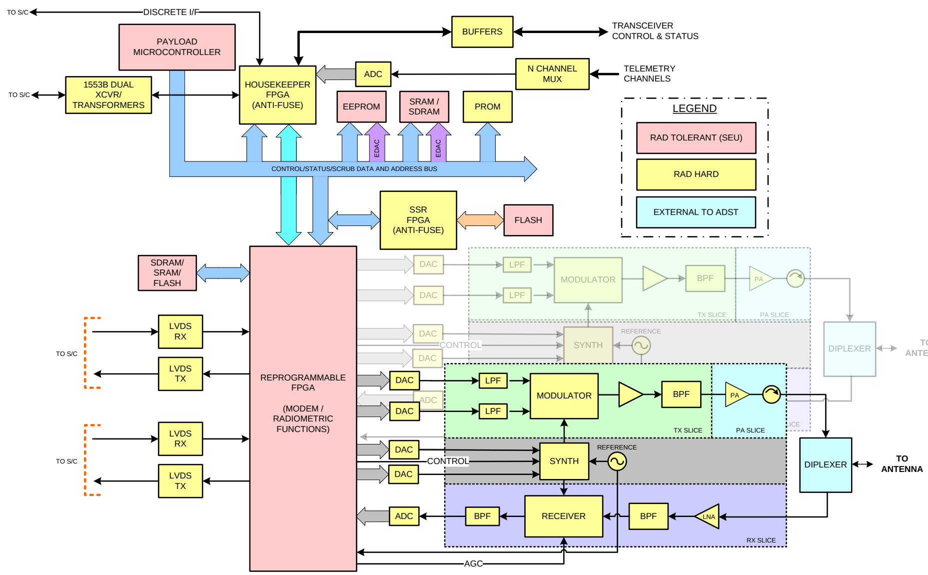
Targeted Users:

- Competed deep space mission sets such as Discovery, Mars Scout, New Frontiers
- Other X and/or Ka-band applications

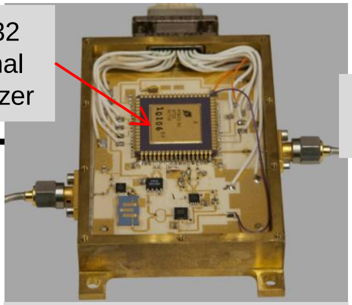
Universal Space Transponder

- Objectives:
  - Develop the universal space transponder (UST) with increased capabilities and reduced costs to support missions launching in 2015 and beyond
  - Multi-function radio
  - Support 150 Mbps min. downlink/25 Mbps uplink
  - Integrated Turbo / LDPC telemetry encoding
  - Uplink channel decoding
  - Support multiple navigation techniques (PN, DOR,CTA)
  - Support multi-band operations (S/X/Ka)
  - Compliant with NASA STRS Architecture
- **Motivation**
  - Replace current transponder that has obsolete parts
  - Provide operational performance enhancement and cost savings to DSN and flight missions

Dual Channel UST Block Diagram



PE97632 Fractional Synthesizer



Reference (76 MHz)

Snapshot of UST 1st LO module under test.

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Participating Organizations:
DSN Advanced Systems; 337

Sponsors: DSN Advanced Systems Program (primary), SCaN Technology Program (secondary – Connect), JPL R&TD (secondary – KaT and RASSI), Cx (secondary – ICCA)

FY09-FY13 Key Milestones

FY09: Level II-IV requirements, receiver breadboard, exciter design, and functional baseband PM

FY10: Full transceiver PM, start EM design and initial development contract, baseband modulation, initiate industry contact

FY11: Complete EM design & start build, complete modulation

FY12: Complete software, EM build, and functional testing

FY13: Complete all testing, including environmental tests

Coding and Modulation

Objectives

- Improve Deep Space link performance via the development and infusion of advanced coding and modulation techniques

Motivation

- Uplink forward error-correcting codes for(a) Emergency communication(b) Command/ARQ(c) File upload(d) Human support
- Hardware implementation and infusion in the Universal Space Transponder (UST)
- Soft-decision Reed-Solomon decoding in DSN
- Simultaneous ranging and telemetry

Outreach

- License and infuse LDPC technology into standards, missions (Cx, MSL, etc.) and ground networks (SN, DSN)

Uplink coding will enable new uplink rates not available today (UST uplink rate of 25 Mbps)

Mode	Purpose	Block Length, kbits	Typical Throughput, kbps	Coding Gain, dB
A	Emergency	0.1	0.01	5
B	Command & ARQ	0.1 - 1	1 - 4	7
C	File upload	1 - 4	1,000	8
D	Human Support	> 4	20,000	9

Task Manager: Jon Hamkins
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Participating Organizations: Information Processing Group,
Section 332Facilities:Information Processing Group FPGA lab

Key Milestones

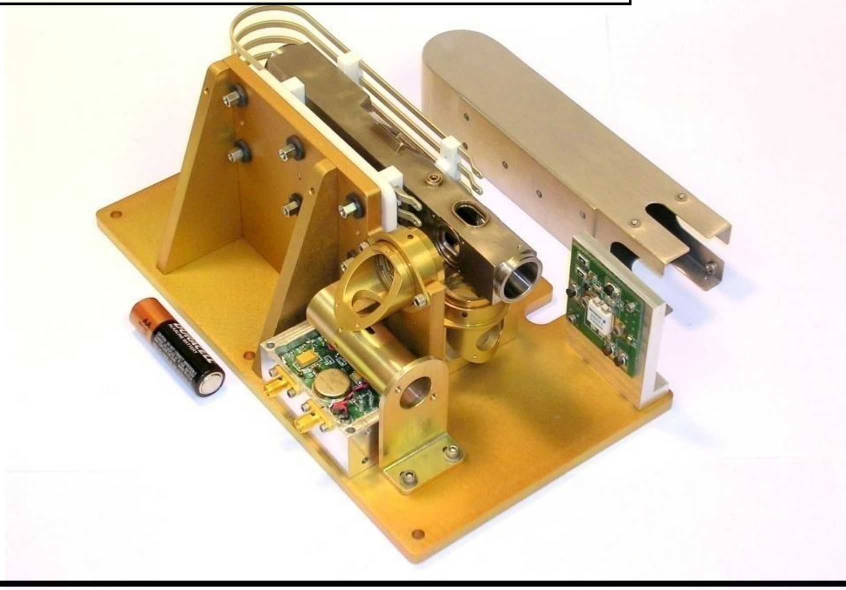
FY08: Initial FPGA uplink encoder/decoder

FY09: Begin UST infusion; Improved RS decoder

FY10-11: Ranging, multiple access technology

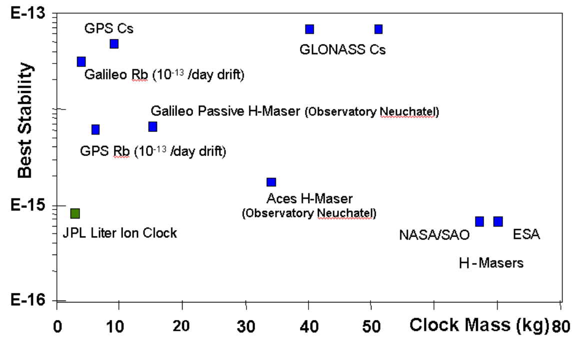
Space Clock

Space-Clock Prototype Assembly



Objectives:

- Develop ultra-stable atomic clock for spacecraft on-board frequency reference for 1-way navigation, downlink only.
- Will enable accurate s/c navigation with less need for specialized uplink DSN passes.



Task Manager: John D. Prestage
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Facilities:

JPL Frequency Standards Lab, B298

Sponsors:

JPL: DSN Advanced Development Program

Milestones

FY06 Demo sealed tube, Thermo-Vac, Team w/ Mars Scout
FY07 Design/Fabricate Physics Package
FY08 Thermal Design, Electronics Design and fab
FY09 Integrate Electronics, I&T Clock, Vacuum Operation, Thermal
FY10 Demo TRL 5 ground operation
FY11 Transition to NASA Mission, GPS III, et al customer base

Low Power, Low Mass Synthesized Ultra-Stable Oscillator

Highlights:

- Small size (12 cm x 10 cm x 7 cm)
- Low mass (480 g)
- Low power (1.1 W steady state)
- Modular 76.5 MHz synthesizer can accommodate all 34 DSN channels
- Frequency is adjustable in-flight
- Low phase noise (-107 dBc/Hz at 10 Hz)
- Low drift rate (~ 4 x 10^{-11} after 96 hours)

Flight Readiness Status:

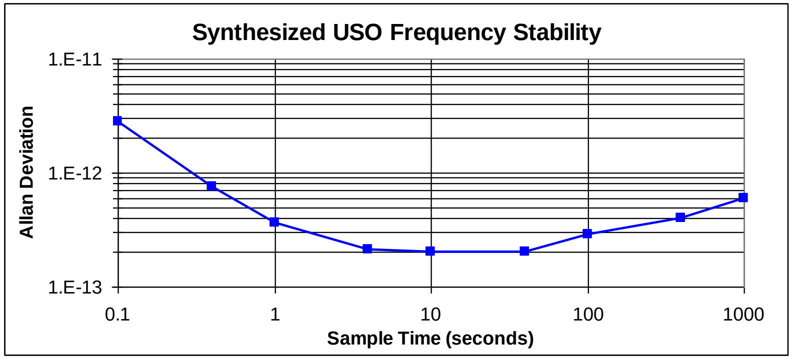
- Prototype qualified to TRL-6 (vibration and thermal vac. tested) under NASA/JPL Mars Technology Program

Prior Technology Heritage:

- Oscillator: TOPEX, Mars Global Surveyor, Cassini, GRACE, CONTOUR
- DDS Synthesizer: New Horizons

Unique Features:

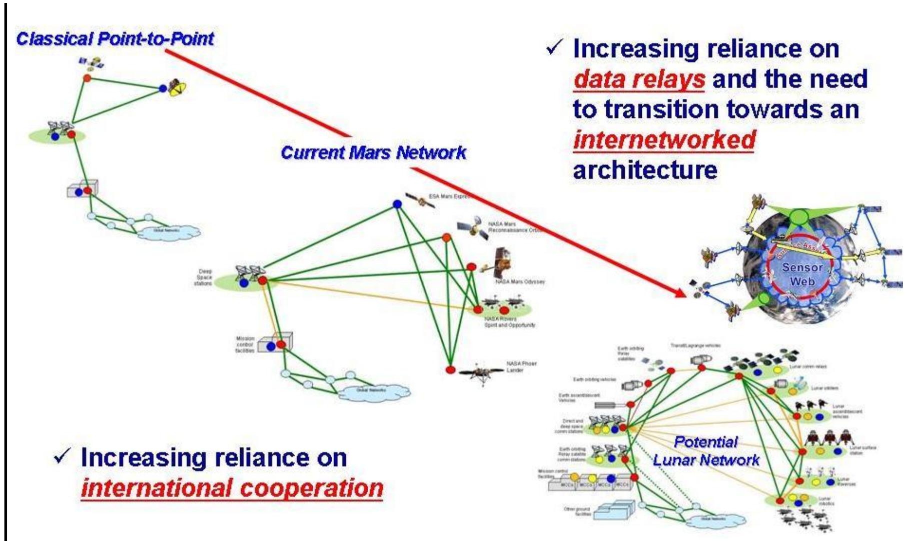
- Synthesized output compatible with SDST
- Excellent short term stability (< 3 x10^{-13})



Disruption Tolerant Networking: Space DTN Project

Objectives

- Rapidly mature the emerging DTN technology to a state of flight readiness for deployment into NASA's missions and space communications architecture by the end of FY'11
  - Complete the specification of core DTN protocol suite
  - Make open-standard DTN implementations available to the international space mission community
  - Demonstrate operational and performance benefits via strategic flight tests:
    - Deep Impact
    - ISS
  - Work with mission designers to facilitate insertion of DTN into flight systems



Rationale

- Increase total mission data return by extending automated networked operations into stressed and disconnected operations environments
  - Improve the timeliness of data delivery
  - Reduce mission risk by providing "anywhere data communications" in highly stressed environments
  - Reduce cost through automation

Status

- Successful Deep Impact Networking Test (DINET-I) conducted in October 2008; preparing for DINET-II to be conducted in September 2009
- DTN now loaded into ISS and ready for checkout
- International CCSDS standardization underway